NASA Facts

National Aeronautics and
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Deep Space Network

NASA's scientific investigations of the solar system are accomplished mainly through the use of robotic spacecraft. The Deep Space Network (DSN) provides the two-way communications link that guides and controls spacecraft and brings back images and other scientific data they collect.

The Deep Space Network encompasses complexes strategically placed on three continents. The largest and most sensitive scientific telecommunications system in the world, it also performs radio and radar astronomy observations for the exploration of the solar system and the universe. It is managed and operated for NASA by the Jet Propulsion Laboratory (JPL).

The predecessor to the DSN was established in January 1958 when JPL, then under contract to the U.S. Army, deployed portable radio tracking stations in Nigeria, Singapore and California to receive signals from -- and plot the orbit of -- Explorer 1, the first successful U.S. satellite.

On December 3, 1958, JPL was transferred from Army jurisdiction to that of the newly created NASA and given responsibility for the design and execution of robotic lunar and planetary exploration programs. Shortly afterward, NASA established the concept of the DSN as a separately managed and operated communications facility that would accommodate all deep space missions, thereby avoiding the need for each flight project to acquire and operate its own specialized space communications network.

Today the DSN features three deep-space communications complexes placed approximately 120 degrees apart around the world: at Goldstone in California's Mojave Desert; near Madrid, Spain; and near Canberra, Australia. This configuration ensures that an antenna is always within sight of a given spacecraft, day and night, as the Earth rotates. Each complex contains up to 10 deep-space stations equipped with large parabolic reflector antennas.

Antennas and Facilities

Each of the DSN complexes has one 70-meter-diameter (230-foot) antenna. These are the largest and most sensitive of DSN's antennas, capable of tracking spacecraft traveling more than 16 billion kilometers (10 billion miles) from Earth. The surface of the 70-meter reflector must remain accurate within a fraction of the signal wavelength, meaning that the precision across the 3,850-square-meter (4,600-square-yard) surface is maintained within one centimeter (0.4 inch). The dish reflector and its mount weigh nearly 2.7 million kilograms (8,000 U.S. tons).

Each complex also has a 34-meter-diameter (112-foot) high-efficiency antenna, incorporating more recent advances in antenna design and mechanics. The reflector surface is precision-shaped for maximum signal-gathering capability.

The most recent additions to the DSN are several 34-meter beam waveguide antennas. On earlier DSN antennas, sensitive electronics were centrally mounted on the hard-to-reach reflector structure, making upgrades and repairs difficult. On beam waveguide antennas, however, such electronics are located in a below-ground pedestal room, with the radio signal brought from the reflector to this room through a series of precision-machined radio frequency reflective mirrors. Not only does this architecture provide the advantage of easier access for enhancements and maintenance, but it also allows for better thermal control for critical electronic components and for more electronics to be placed in the antenna to support operation at multiple frequencies. Three of these new antennas have been built at Goldstone, along with one each at the Canberra and Madrid complexes

There is also one 26-meter-diameter (85-foot) antenna at each complex for tracking Earth-orbiting satellites, which are in orbits primarily 160 to 1,000 kilometers (100 to 620 miles) above Earth. The two-axis astronomical mount allows these antennas to point low on the horizon to pick up fast-moving Earth-orbiting satellites as soon as they come into view. They can track at up to three degrees per second.

Each complex has also recently added one 11-meter (36-foot) antenna each to support a series of international Earth-orbiting missions under the Space Very Long Baseline Interferometry project.

All of the antennas communicate directly with the control center at JPL in Pasadena, California, the operations hub for the network. The control center staff directs and monitors operations, transmits commands and oversees the quality of spacecraft telemetry and navigation data delivered to network users.

In addition to the DSN complexes and the control center, a ground communications facility provides communications linking the three complexes to the control center at JPL, to flight control centers in the United States and overseas, and to scientists around the world. Voice and data traffic between various locations is sent via land lines, submarine cable, microwave links and communications satellites.

The Radio Link

The Deep Space Network's radio link to spacecraft is basically the same as other point-to-point microwave communications systems, except for the very long distances involved and the very low spacecraft signal strength. "Very low" might be an understatement: the total signal power arriving at a network antenna from a spacecraft encounter among the outer planets can be 20 billion times weaker than the power level in a modern digital wristwatch battery.

The extreme weakness of the signal results from restrictions placed on the size, weight and power supply of the spacecraft by the cargo area and weight-lifting limitations of the launch vehicle. Consequently, the design of the radio link is the result of engineering tradeoffs between spacecraft transmitter power and antenna diameter, and the sensitivity that can be built into the ground receiving system.

Typically, a spacecraft signal is limited to 20 watts, or about the same power required to light a refrigerator bulb. When the signal arrives at Earth from outer space -- say, from the neighborhood of Saturn -- it is spread over an area with a diameter equal to about 1,000 Earth diameters. As a result, the ground antenna is able to receive only a very small part of the signal power, which is degraded by background radio noise, or static.

Noise is radiated naturally from nearly all objects in the universe, including Earth and the sun. Noise is also inherently generated in all electronic systems, including the DSN's own detectors.

Since there will always be noise amplified with the signal, the ability of the ground receiving system to separate the noise from the signal is critical. The DSN utilizes state-of-the-art, low-noise receivers and telemetry coding techniques to create unequaled sensitivity and efficiency.

What is telemetry? It is the transmission of data to or from a spacecraft by radio waves. In other words, when we're discussing spacecraft sending messages to Earth, telemetry is engineering data and information about the spacecraft's own systems, produced by its own scientific instruments. It is transmitted in binary code, using only the symbols 1 and 0.

The spacecraft organizes and encodes data for transmission to ground stations which have equipment to detect the individual bits, decode the data stream and format the information for transmission to the data user.

That transmission can be disturbed by noise from various sources that interferes with the decoding process. If there is a high signal-to-noise ratio, the number of decoding errors will be low. But if the signal-to-noise ratio is low, bit errors can be excessive; the data transmission rate, measured in bits per second, must be reduced to give the decoder more time to determine the value of each bit.

To help solve the noise problem, additional or redundant data are fed into the data stream and are used to detect and correct errors after transmission. The equations used in this process are sufficiently detailed to allow individual and multiple errors to be detected and corrected. After correction, the redundant digits are eliminated from the data, leaving a validated sequence of information to be delivered to the data user.

Error detecting and encoding techniques can increase the data rate many times over transmissions that are not coded for error detection. DSN coding techniques have the capability of reducing transmission errors in spacecraft science information to less than one in a million.

But telemetry is a two-way street. We on Earth can send commands, computer software and other crucial data up to our spacecraft, giving us the ability to guide the spacecraft on their planned missions, as well as to upgrade a spacecraft's onboard software, among many other capabilities, in order to enhance mission objectives.

Data collected by the DSN is also very important in precisely determining a spacecraft's location and trajectory. This tracking data is used by teams of mission navigators teams to plan all the manuevers needed to ensure the spacecraft is at the right place to collect its valuable scientific data. This tracking data allows us to know the location of a spacecraft that is billions of kilometers from Earth to an accuracy of just a few meters.

Arraying Antennas

When a single antenna is unable to capture a spacecraft signal by itself, the DSN uses a technique called "arraying" to combine the signal from two or more antennas. The improvement in performance from arraying may be the only way to capture an extremely weak signal, or, in some cases, to allow for a higher data rate. The DSN's ability to array its own antennas together, as well as arraying with antennas from other agnecies, has been used several times to increase the science data capture from deep space missions.

A dramatic example of arraying on an international scale came in the fall of 1996. An intercontinental link-up of the DSN's antennas in Australia and Goldstone was developed to retrieve the maximum amount of data possible from NASA's Galileo spacecraft, whose planned high-speed, high-power telecommunications voice had been reduced to a whisper when its main antenna failed to open four years earlier. The combining of the signals from up to four DSN antennas, plus the Parkes Radio Telescope in Australia, operated by the Commonwealth Scientific and Industrial Research Organization (CSIRO), together with new data encoding techniques, increased the raw data return over ten times what would have otherwise been possible.

The DSN has also used antennas from other international agencies to help support arraying efforts for the Voyager project's successful fly-bys of Uranus and Neptune. These antennas included the twenty-seven 25-meter (82-foot) antennas of the Very Large Array (VLA) in Socorro, New Mexico, operated by the National Radio Astronomy Observatory, and the Usuda 64-meter (210-foot) antenna operated by the Japanese Institute of Astronautical Sciences (ISAS).

Another advantage of arraying is that several smaller antennas can be combined to provide the same performance of a single large antenna.This was one of the key reasons for constructing three of the new34-meter beam waveguide antennas at Goldstone. Following sophisticated software upgrades now in the works, the four 34-meter (112-foot) antennas at Goldstone will be able to create the equivalent capability of a 70-meter antenna by 1999. Goldstone has long featured a 70-meter (230-foot) antenna; beginning in 1999, the 34-meter (112-foot) array will be available in the event that significant downtime is needed on the 70-meter)230-foot) antenna, enabling the DSN to continue to meet its commitments.

Science

The DSN is a multi-faceted science instrument used to improve our knowledge of the solar system and the universe. It uses its large antennas and sensitive instruments to perform radio astronomy, radar, and radio science experiments. The antennas acquire information from signals emitted or reflected by natural celestial sources. Those data are compiled and analyzed by scientists in disciplines including astrophysics, radio astronomy, Earth physics, planetary radar, gravitation and relativity.

Among many other science projects, the DSN provides the information needed to: help select landing sites for space missions; determine the composition of the atmospheres and surfaces of the planets and their moons; search for bio-genic elements in the galaxy; study the star formation process; image asteroids; investigate comets, particularly their nuclei and comas; search for ice on the moon and Mercury; and confirm the theory of general relativity.

The DSN radio science system performs experiments which allow scientists to characterize the atmospheres and ionospheres of planets, determine the compositions of planetary surfaces and rings, look through the solar corona, and determine the mass of planets, moons and asteroids. It does this by precisely measuring small changes in the spacecraft signal as the radio waves are scattered, refracted, or absorbed by particles and gases near solar system objects.

The DSN makes its facilities available to qualified scientists as long as the research does not interfere with spacecraft mission support.

Astronomical Interferometry

An important DSN activity is radio interferometry, traditionally involving widely separated radio telescopes on Earth -- but now taking an astronomical turn with the use of Earth-orbiting satellites as additional antennas out in space. Interferometry is a technique used by radio astronomers to electronically link radio telescopes so they work as if they were a single instrument with the resolving power of a single dish with a diameter equal to the separation between the individual dishes. Now a VLBI space radio telescope is being taken into space for the first time.

NASA and the National Radio Astronomy Observatory have joined with an international consortium of space agencies to support the launch of a Japanese satellite creating the largest astronomical “instrument” ever built, a radio telescope more than two-and-one-half times the diameter of the Earth. This interferometry experiment was made possible by the February 1997 launch of the Very Long Base Interferometry Program satellite by Japan’s Institute of Space and Astronautical Science. It approximately triples the resolving power previously available from ground-based telescopes — in fact, its resolving power is equivalent to being able to see a grain of rice in Tokyo from Los Angeles.

In 1999, Russia is scheduled to launch its RadioAstron Space Radio Telescope, eventually linking with the DSN to create a second Earth-space interferometer. Early in the next century, the DSN will use astronomical interferometry in cooperation with Japan and Russia to pursue such science objectives as the production of high-resolution maps of quasars and the search for high-brightness temperature components in compact extragalactic sources.

Teams

Gael Squibb is director of JPL’s Telecommunications and Mission Operations Directorate (TMOD). Richard Coffin is TMO program manager. The TMOD Plans and Commitments Program Office is managed by Richard B. Miller. Terry D. Linick is TMOD Operations Program Office manager and Joseph Statman is TMOD Engineering Program Office manager. The TMOD Technology Program Office is managed by Leslie Deutsch.

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